Forces and Motion
Teacher Background Information (SC040300)

A force is often defined as a push or a pull. Although this is an accurate description for students, there is much more to be understood. This is an area about which students hold many misconceptions; it deserves significant time and in-depth exploration by students at this age.

A force is an indication of kinetic energy—energy of motion. It can change a structure, start or stop motion, speed or slow motion, or change the direction of motion. This unit does not address forces that change the internal structure of materials; that will be covered in grade 7 (Physical and Chemical Changes, SC070300). Each force has a definite strength (which physicists call *magnitude*) and a direction. To describe a force accurately, we must indicate both its magnitude and direction; physicists call quantities like force that have two parameters *vectors.* They often show forces with arrows, where the strength of the force is the length of the arrow. This is an excellent graphic organizer even at the elementary level. Teachers can avoid potential misconceptions by always diagramming forces with proportional arrows that show strength and direction. The arrows need not be exactly proportional, but should be consistent and logical.

Many forces act on an object at the same time. For example, if a book were on a table, many people would identify the downward force of gravity on the book. But it is easy to understand that (assuming the table is solid) it exerts an equal upward force on the book. (Physicists often call this the *normal* force.) If the forcers were not exactly balanced (say, if the table were very thin and it broke) then the book would move. For a student going down a playground slide there is the downward force of gravity, the push of the slide (upward perpendicular to the surface) and friction and air forces resisting forward motion. What the students will actually show is the net (*resultant*) motion on the student, which is the unbalanced geometric sum of all of these forces. It should be an arrow parallel to the surface of the slide. In higher physics, students use trigonometry to add these forces (which act at different angles) and predict the movement that will occur from the *net* force. Students at the elementary level simply observe the motion, and infer that an unbalanced force exists in the direction of the motion.

From ancient times people had the misconception that force needed to be continuously applied in order to keep an object going. Aristotle described a force as being "used up" as an object traveled along. Galileo first explored the idea of inertia. Inertia is the property of matter at rest to remain at rest, or in motion to remain in motion, until acted on by another force. The reason most people find inertia hard to understand is that on Earth there is almost no example of motion without friction, which is a force that opposes motion and slows an object down. However, in outer space where there are very few molecules and almost no friction, a spaceship in motion would remain in motion almost forever until it bumped into [was pushed by] another object. Inertia was quantified and ultimately accepted after the publication of Isaac Newton's *Principia* about 100 years after Galileo. Students can explore inertia through the video *Toys in Space* (NASA, referenced) that shows astronauts playing with familiar toys in the frictionless freefall environment of the space shuttle. **Note:** The space shuttle is not gravity-free; the astronauts are in freefall, which simulates lack of gravity.

Friction can be defined as "resistance to motion." It is related to the roughness of materials as they move across one another, and also to the force with which the materials are pressed together; i.e., their weight. Students can easily understand that friction reduces (subtracts from) a force which might otherwise push something forward; for example, a push to a student on inline skates has more effect than if the student is wearing shoes, because the skate wheel does not rub across the surface of the road like a shoe would.

We can measure the strength of a force by noting changes of shape or motion. When we use a spring scale we change the shape of a spring proportional to the strength of the force. We can also compare forces by noting the change in motion of objects of similar shape and mass. Forces also change the shape or structure of things; for example, squashing a ball of putty or stressing a steel joist. However, these forces are more difficult to see and more appropriate for older students.

Misconceptions

One of the most persistent misconceptions in physics—one disproved by Galileo himself—is that heavy objects fall faster than light ones. "Falling" is the effect of the force of gravitation, which is determined by the product of the mass of the planet (Earth) and the mass of the object (when it is not opposed by an equal, opposite force.) It is easy to understand that differences in small objects could not possibly change the product of their mass and the mass of the enormous Earth enough to notice! So why do so many people think heavy things fall faster? The answer is in the air. Wind resistance can change the rate of fall of objects significantly. So when we allow students to discover the (lack of) effect of mass on rate of fall, it is important to have objects of the same size and shape—like a ping-pong ball and a golf ball—rather than very different objects.

Teachers should take the time to read about misconceptions in students before they address this unit. (They often discover that they have harbored some themselves!) Two excellent sources are:

Stavy, Ruth, and Dina Tirosh. *How students (Mis-)Understand Science and Mathematics.* New York: Teachers College Press, 2000.

Stepans, Joseph. *Targeting Students' Science Misconceptions.* Riverview, FL: Idea Factory, Inc. 1994.

Measurements

Measuring force is easy in the English system, because we commonly refer to different masses by their weight (the force of gravity on them). The pound is a unit that describes the force of gravity on a certain quantity of mass as it falls to Earth. That same mass would be subject to a different force on the moon and have a different weight in pounds. But in the metric system the kilogram is a unit of mass. 1 K of lead on Earth is still 1 K on the Moon. The metric unit of force, the Newton, is roughly equal to the force the Earth exerts on about 0.1 kg of mass.

Measurement and estimation of forces are important goals for this unit, and make ideal areas to integrate with mathematics. If your mathematics text uses metric units, metric spring scales will be a good investment. (Make sure that you get strong enough scales so that students can measure books and toys, since they will try anyway.) If you do not need to use the metric units for force in your mathematics curriculum you can also purchase spring scales in English units and do the entire unit using the English system.

A good source for supplementary experiments on measuring forces is: Graham, John. *Hands-on Science.* New York: Kingfisher, 2001. This slim paperback is addressed at students and shows many optional activities for this unit with simple materials, including several ways for students to build their own force measuring devices (similar to spring scales).

Ordering Materials

Many of the materials in this unit can be scavenged or made inexpensively. Using your newsletter or a letter home to parents in advance can make the unit much easier. Blocks of wood are conveniently purchased from hobby stores under the heading *Pinebox Derby.*

The Push Pop wheels and axles can be purchased separately from the ice cream by contacting Nestle Dairy, PO Box 1819, Columbus Ohio. Phone: 1-614-294-4931